Adult Chinook Escapement Assessment Conducted on the Nanaimo River During 2004

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ABSTRACT

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In 2004, Fisheries and Oceans Canada in co-operation with Snuneymuxw First Nation and Nanaimo River Hatchery continued an escapement study of chinook salmon (*Oncorhynchus tshawytscha*) in the Nanaimo River. Areas of concentration for this study included: i) calculating Petersen population estimates through carcass mark-recapture surveys for both fall run and First Lake spring run chinook; ii) generating an area-under-the-curve population estimate by conducting swim surveys in the lower Nanaimo River for fall run chinook; iii) enumerating spring run chinook by aerial overflights; and iv) collecting biological and coded-wire tag (CWT) data. The estimated total return of fall run adult chinook to the Nanaimo River was 2,230 of which 1,891 spawned naturally. We used aerial surveys between Wolf Creek and First Lake as well as information compiled during hatchery broodstock collection to estimate the naturally spawning population of the First Lake spring chinook to be 200 fish and the total return to be 306 fish. Total return of all chinook in the Nanaimo River system in 2004 was 2,549 adult fish.

RÉSUMÉ

Hop Wo, N.K., Carter, E.W., and Matthews, I. 2006. Adult chinook escapement assessment conducted on the Nanaimo River during 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. 2766: 44 p.

En 2004, Pêches et Océans Canada, en coopération avec la Première nation Snuneymuxw et l'écloserie de Nanaimo River, a poursuivi l'étude sur l'échappée du saumon quinnat (*Oncorhynchus tshawytscha*) dans la rivière Nanaimo. L'étude visait quatre buts : i) obtenir une estimation des effectifs de la remonte de quinnats d'automne et de la remonte de quinnats de printemps du lac First selon la méthode de Petersen par le biais de relevés de dénombrement des carcasses des individus marqués; ii) obtenir une estimation de la population d'après la surface sous la courbe par le biais de relevés de dénombrement en plongée libre des quinnats d'automne présents dans la rivière Nanaimo inférieure; iii) dénombrer les quinnats de printemps par relevés aériens; et iv) recueillir des données biologiques et des données de micromarques magnétisées codées. Selon les estimations, la remonte d'automne de quinnats adultes dans la rivière Nanaimo totalisait 2 230 individus, dont 1 891 ont frayé naturellement. Nous avons utilisé les résultats des relevés aériens effectués entre le ruisseau Wolf et le lac First, ainsi que l'information recueillie lors du prélèvement de reproducteurs d'écloserie, pour estimer les effectifs de la population de quinnats de printemps qui se reproduisent naturellement dans le lac First. Ce nombre se chiffrait à 200 individus, et la remonte totale à 306 individus. En 2004, la remonte totale de quinnats dans le réseau de la rivière Nanaimo se chiffrait à 2 549 individus.

INTRODUCTION

Since 1988, considerable interest has been focused on the status of chinook salmon (*Oncorhynchus tshawytscha*) stocks in the lower Strait of Georgia. The Nanaimo River along with the Cowichan River and the Squamish River, were chosen to represent the lower Strait of Georgia as exploitation and escapement indicator rivers (PSC 1990). Escapement information is used to evaluate rebuilding strategies and harvest management policies for lower Strait of Georgia chinook (Farlinger et al. 1990). Since then, due to logistical reasons the Squamish River system was dropped as an indicator. The Nanaimo River system was also dropped as an exploitation rate indicator in 2002 and the enumeration fence was discontinued the following season, in 2003. However, the Nanaimo River system remains an important escapement indicator for lower Georgia Strait chinook with the unique distinction of monitoring one fall and two spring runs. In 2004, DFO, Science Branch, in conjunction with Snuneymuxw First Nation and the Nanaimo River Hatchery continued to operate a carcass mark-recapture and swim survey program to collect information on chinook escapements.

Nanaimo River chinook exhibit a variety of life history strategies, with at least three genetically distinct runs produced (Carl and Healey 1984). Unique to only a few systems on the East coast of Vancouver Island, there are two distinct spring chinook stocks in additional to a fall run stock returning to the Nanaimo River (Figure 1).

The two spring run stocks enter the river from between December and February and hold in First Lake, Second Lake or deep canyon pools until they spawn during late summer/early fall (Blackman 1981, Brahniuk et al. 1993, Nagtegaal and Carter 2000). The Upper Nanaimo River spring chinook stock spawns upstream of Second Lake to Sadie Creek at the outlet of Fourth Lake in October (Hardie 2002). The majority of fry are stream-type which rear for up to one year before outmigrating to the estuary (Healey 1980, Blackman 1981, Nagtegaal and Carter 2000).

The First Lake spring run spawns within the first 1.6 kilometers downstream of the First Lake outlet to the Wolf Creek junction pool (Healey and Jordan 1982, Hardie 2002), with the peak of spawning typically during the first two weeks of October (Nagtegaal and Carter 2000, Brahniuk et al., 1993). Chinook fry produced from the late spring run are mostly ocean-type and rear for 90 days in freshwater before migrating to sea. Stream-type fry will be more vulnerable to changes in freshwater productivity and habitat conditions than ocean-type fry that outmigrate upon emergence. Once in the estuary, First Lake fry exhibit greater agonistic behaviour than fry produced by the lower Nanaimo stocks due to their longer period of territorial stream residence prior to migration into the estuary (Taylor 1990).

The larger fall chinook stock enters the Nanaimo River during August/September and a large proportion of the run spawns in the lower river downstream of the Borehole/lower canyon area down to the Cedar Road bridge (Healey and Jordan 1982, Hardie 2002). Some of the fall chinook run ascend the falls to spawn in the upper river downstream of First Lake. The majority (99%) of fry incubated in the lower river exhibit ocean-type life history strategy and outmigrate to sea upon emergence to rear in the estuary (Healey and Jordan 1982).

Hatchery production of chinook on the Nanaimo River began in 1979 (Cross et al. 1991). In that first year, eggs were incubated at the Pacific Biological Station and later released into the river. The first year of production at the hatchery facility was 1980 (1979 brood) when 100,000 fall run chinook fry were released. Over the years fry production has increased, and in 2004, a total of 120,199 fall run chinook fry and 187,214 First Lake spring run chinook were released into the Nanaimo River Watershed. There is no hatchery enhancement for the Upper Nanaimo River spring run chinook stock. Coded-wire tagging of chinook began in 1979 and by 2003, 19.8% of fall run chinook fry carried coded-wire tags; however, no CWT chinook were released in 2004 (P. McKay, Nanaimo River Salmonid Enhancement Project Co-Manager, Community Futures Development Corporation of Central Island, 271 Pine Street, Nanaimo, B.C., V9R 2B7. pers. comm.).

In addition to chinook, the Nanaimo River also supports stocks of coho salmon (*O. kisutch*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), steelhead trout (*O. mykiss*), cutthroat trout (*O. clarki*), and Dolly Varden (*Salvelinus malma*).

In consultation with various user groups, the B.C. Ministry of Environment, Lands and Parks initiated a Nanaimo River Water Management Plan in June 1989. The primary goal of the plan was to improve salmon escapement by increasing flows during typically low water levels in the fall while at the same time maintaining adequate flows to satisfy industrial and domestic water use (Ministry of Environment, Lands and Parks 1993).

This report presents the results of the study completed during 2004. The objectives included:

1. providing fall run and First Lake spring run chinook salmon estimates for the Nanaimo River Watershed,
2. estimating the First Nations food fishery catch,
3. recording hatchery broodstock removals of fall and spring run chinook,
4. implementing a carcass mark-recapture study for both fall run and First Lake spring run chinook,
5. collecting biological data and sampling coded-wire tag (CWT) recoveries, and
6. generating an area-under-the-curve (AUC) estimate through swim surveys in the lower Nanaimo River.

METHODS

Three methods were employed to estimate chinook spawning escapement in the Nanaimo River. These included, carcass mark-recapture techniques, swim surveys, and an aerial overflight. The pooled Petersen mark-recapture calculation was used to generate a chinook population estimate, while an AUC estimate was also generated using swim survey information. Biological data including length, sex, scales, presence/absence of an adipose fin, and coded-wire

tagged heads were collected from carcasses during the mark-recapture and broodstock collection programs.

MARK-RECAPTURE AND BIOLOGICAL DATA COLLECTION

Escapement estimates were generated from mark-recapture data using the pooled Petersen model (Chapman modification; Ricker 1975) for both the fall run and First Lake spring run adult and jack chinook. The mark-recapture also provided information on length frequencies, age compositions, and sex composition. CWT data was also collected to be used in calculating enhanced (hatchery) contribution in the Nanaimo River Watershed.

The carcass recovery operation involved a two or three-person crew in an inflatable boat searching the river daily for spawned out chinook carcasses. Each carcass was tagged with a numbered Ketchum[1] aluminum sheep ear tag on the left operculum and released into the river. Fish were also hole punched in the left operculum in case the aluminium tag was lost. For all recaptures, the tag number and location were recorded. Once recaptured, the carcass was cut up and removed from the river to avoid multiple recaptures. Biological information such as post orbital-hypural (POH) length, sex, capture location, and the presence or absence of an adipose fin were recorded. If the adipose fin was missing the head was catalogued and taken for CWT analysis at the laboratory. Five scale samples were taken from the preferred area to be analysed for age composition (Shaw 1994). Otoliths were also collected from chinook to assess the possibility of strays from Robertson Creek Hatchery. Chinook fry released from this hatchery have been exposed to varying temperatures and as a result, have a specific pattern on their otoliths.

Recovery effort was concentrated on two sections of the Nanaimo River Watershed. The lower portion concentrated on sampling fall run chinook which spawned between the Island Highway Bridge and the Cedar Bridge. Carcass mark-recapture in the upper portion of the Nanaimo River Watershed targeted First Lake spring run chinook which spawned in a two kilometer stretch of river, between the outlet of First Lake and the Wolf Creek outlet.

Biological information similar to that recorded for the carcass mark-recapture was provided by the Nanaimo River Hatchery staff from chinook collected for purposes of broodstock. This included both fall run chinook and First Lake spring run chinook.

Mark-recapture estimates were calculated using a pooled Petersen estimator. Since the true population size was not known, a direct measure of the accuracy of the estimates was not possible. However, an assessment of the underlying assumptions of equal probability of capture, simple random recovery sampling, and complete mixing can usually be made by testing recovery and application samples for temporal, sex, and size related biases (Schubert 2000). To carry out most of the bias assessments, different gear types must be utilized for capturing the tag

[1] Ketchum Manufacturing Ltd., Ottawa, Canada

application and the recovery samples. In the current study, the spawning ground carcass recovery was used to attain both samples thus limiting the ability to assess sample biases.

Finding sampling biases usually results in the use of a stratified estimator; however, Schubert (2000) compared the performance of several mark-recapture population estimators for a sockeye salmon population of known abundance and concluded that the pooled Petersen estimator was less biased and preferred over stratified estimators. In that study, the Schaeffer estimator would not improve accuracy and it was recommended that the method be abandoned for use in population estimation. Also, it was determined that while the maximum likelihood Darroch estimator could potentially improve accuracy there was no obvious way of selecting between accurate and highly biased estimates. Parken and Atagi (2000) found that pooled and stratified estimators of Nass River summer steelhead produced similar escapement estimates but that the pooled estimator was more precise and had less statistical bias than the stratified estimator. These findings indicate the robust nature of the pooled Petersen estimator and suggest that its use to determine population abundance from mark-recapture data is generally appropriate under a wide range of circumstances.

SWIM SURVEYS

Nanaimo River Hatchery staff conducted and coordinated swim surveys to provide an independent estimate of spawning chinook as well as to assess spawning distribution throughout select portions of the river. Swim surveys were normally carried out using four swimmers staying abreast of each other while moving downstream. Swimmers combined individual counts, which were recorded by pre-defined localities in the river (Figure 2). In the lower portions of the river these counts were combined into four segments to allow area-under-the-curve (AUC) analysis (English et al. 1992).

AERIAL SURVEY

A single overflight was conducted on 21 October, primarily for the enumeration of chum salmon on the lower Nanaimo River (Island Highway Bridge to the Estuary). The flight path also allowed an estimate of chinook abundance in the Nanaimo River. The helicopter, a Eurocopter A-Star, was flown at low altitude, approximately 300 feet (~91.4 m), to aid in visibility as well as the identification of salmon species. Counts were made by river pool or river section and combined to obtain a final estimate.

WATER MANAGEMENT PLAN

The low flow and water levels likely result in delayed fish movement and higher water temperatures which may potentially increase levels of disease and parasites. This is particularly true for the parasite Ich (*ichthyophthirius*) which matures more rapidly with higher temperature

(Ministry of Environment, Lands and Parks 1993). During particularly low water levels the river flow can be increased with a controlled water release.

Two man-made reservoirs in the Nanaimo River system have been utilised to increase flows during periods of low flow between late summer and early fall. Prior to 1989, water releases were conducted based on an informal arrangement between local Fisheries Officers and Harmac Pacific. Fisheries Officers would request a water release when, in their opinion, fish holding in the lower river became threatened due to low water. These requests would be granted by Harmac dependent upon the availability of water in reserve.

With the increase in population in the Nanaimo area and in an effort to satisfy domestic, industrial, agricultural, fishery, wildlife, and recreational needs; a Nanaimo River Water Management Plan was initiated by the B.C. Ministry of Environment (BCMOE) in June 1989. A team comprised of members from the BCMOE, Greater Nanaimo Water District, MacMillan Bloedel Limited, Snuneymuxw First Nation, and Fisheries and Oceans Canada (DFO) negotiated a water flow management plan (Ministry of Environments, Lands and Parks 1993). The primary water management issue has been to enhance flows to meet fisheries requirements while maintaining flows to satisfy industrial and municipal needs. This is particularly important during periods of lowest flow (September and October) and in the ten kilometer section of river below the Harmac Pulp Operations water intake area. Increases in the fall water releases from the reservoirs since 1989 have encouraged spawning migration.

The Nanaimo River Water Management Plan also incorporates the ramping (a gradual increase and/or decrease) of water levels to minimize effects of sudden changes in river dynamics. Possible effects include the stranding of fish, alteration of river hydrology, and erosion of river banks. The recommended minimum duration of a water release is 48 hours, with the optimum release time being three to four days. The recommended minimum discharge for a water release is 14.87 m^3/s (525 ft^3/s), to be released from Fourth Lake (Hop Wo et al. 2005).

RESULTS

CARCASS MARK-RECAPTURE

The carcass mark-recapture program was divided into two recovery areas, the lower Nanaimo River and the upper Nanaimo River. Daily Nanaimo River discharge for the duration of the carcass mark-recapture is presented in Table 1 and Figure 3.

Lower Nanaimo River

The lower Nanaimo River carcass mark-recapture commenced on 01 November and was discontinued on 02 December 2004. Carcass mark-recapture data were slightly adjusted to account for discrepancies between age classes as denoted from the field data versus scale data. Age information provided from scale data was preferred as four adults and one jack were found

to have been incorrectly identified. During this period 29 male, 36 female and ten jack chinook carcasses were tagged and released in the lower Nanaimo River (Table 2A). Of the 15 carcasses recaptured with tags, eight (53.3%) were male, seven (46.7%) were female and no jack chinook were recaptured. Using the Petersen estimator, the total fall run adult chinook population estimate was 334 fish (95% CI: 191 – 477) (Table 3A). As no jack chinook were recaptured, no Petersen estimate could be calculated.

Potential Biases

The assessment of sampling selectivity had several potential biases in the carcass mark-recapture study.

1. Temporal Bias: Temporal bias in the tagging sample was examined by stratifying the mark incident rate into four recovery periods (Table 4A). There was no detectable temporal bias for male or female chinook when stratified into identical recovery periods (Chi-square = 4.10; $p<0.01$; Chi-square = 1.55, $p<0.01$, for male and female chinook, respectively).

Temporal bias in the recovery sample was analysed by stratifying the recovery rates into four application periods (Table 5A). A statistical difference in the recovery sample for adult male chinook was observed (Chi-square = 15.65; $p<0.01$). Alternatively, there was no statistical bias for female chinook (Chi-square = 2.46; $p<0.01$).

2. Fish Sex: Sex related bias was examined by comparing the sex ratio of the marked and unmarked spawning ground recoveries by application sample and by recovery sample. No sex related bias was evident when comparing male and female chinook populations (Chi-square = 0.60; $p<0.01$ and Chi-square = 0.37; $p<0.01$, application sample and recovery sample, respectively) (Table 6A). When jack chinook were included into the application and recovery samples no significant bias was apparent (Chi-square = 3.55; $p<0.01$, and Chi-square = 2.88; $p<0.01$, application sample and recovery sample, respectively) (Table 7).

3. Size Bias: Size related bias was examined by comparing the POH mean lengths of unrecovered marked chinook and recaptured chinook by sex. No size bias was evident in the recovery sample of adult male and adult female chinook (Student's t-test: $t = 0.522$; $p<0.05$ and $t = 1.197$; $p<0.05$, for males and females, respectively).

Upper Nanaimo River

The upper Nanaimo River carcass mark-recapture commenced on 03 November, occurred over 16 days, and was discontinued on 01 December 2004. There were no discrepancies between age classes as denoted from the field data and those obtained from scale age data. During this period 16 male and ten female were tagged and released in the upper Nanaimo River (Table 2B). No jack chinook were recovered in the upper Nanaimo River. Of the ten carcasses recaptured with tags, seven (70.0%) were male and three (30.0%) were female. Using the Petersen

estimator, the total adult First Lake spring run chinook population estimate was 91 fish (95% CI: 47 – 134) (Table 3B).

Potential Biases

The assessment of sampling selectivity had several potential biases in the carcass mark-recapture study; however, the small sample size did not allow for rigorous Chi-Square and Student t-test analysis. Table 4B shows tagged recoveries by recovery period; similarly, Table 5B shows the percentage of tagged recoveries by application period. Table 6B notes sex composition by tag application and recovery samples for chinook carcasses recovered in the upper Nanaimo River.

SWIM SURVEYS

Eleven swim surveys were conducted in the lower portion of the Nanaimo River between the Highway Bridge Pool to the Raines Road Pool, 650 meters downstream of the Cedar Bridge. Swims occurred between 09 September and 19 November 2004 (Table 8A). Surveys were differentiated into four segments which contained multiple adjacent pools and riffle sections, specifically, Segment 1, Bridge Pool to Alder Run; Segment 2, Haslam Creek Junction to House Pool; Segment 3, Maffeo Side Channel to Cedar Firehall; and Section 4, Barn Hole to Raines Road Pool (Figure 2). Daily Nanaimo River discharge during the course of the swim surveys is presented in Figure 3.

In calculating an AUC estimate a survey life statistic is required. Survey life is the average time a chinook salmon can be counted within the swim survey area, between Bridge Pool and Raines Road Pool (Figure 2). This statistic is generally calculated through the implementation of a tagging program; however, this has not been completed on the Nanaimo River. A survey life statistic of 17.8 days was used to calculate the Nanaimo River chinook AUC estimate; this was obtained by averaging the 2001 and 2002 survey life statistics for Englishman River chinook. A start date of 20 August was chosen as a time just before chinook entered the survey area (H. Bob. Nanaimo River Salmonid Enhancement Project Co-Manager, Community Futures Development Corporation of Central Island, 271 Pine Street, Nanaimo, B.C., V9R 2B7. pers comm.). The last swim date used in AUC calculations was 15 November, this assumes that no other chinook were available for counting after this date.

Another factor used in calculating an AUC estimate is observer efficiency, which accounts for chinook missed by observers. Factors affecting observer efficiency are water turbidity and lighting conditions, as well as areas were fish can hide, for example, deep pools or log jams. Observer efficiency ranged from 80% - 95% for most of the swim surveys. Two exceptions were on 08 October, which was deemed unreliable and excluded from AUC calculations, and 15 November, where poor visibility was also noted (Table 8A and Table 9A).

The calculated AUC estimate for fall run adult chinook in the lower Nanaimo River is 1,998 fish. Swims conducted between 14 October and 04 November were slightly adjusted for broodstock removals. One swim survey, 08 October, was not included in AUC calculations because conditions were poor. Swim survey counts with expanded estimates are presented in Table 9A and Figure 5.

An AUC estimate was also generated for fall run jack chinook within the lower Nanaimo River using the same survey life (17.8 days) and observer efficiencies as adult chinook. No adjustments were made to jack chinook to account for hatchery broodstock removals. This methodology yielded 220 jack chinook. Swim survey counts with expanded estimates are presented in Table 9B and Figure 5.

In addition, two swim surveys were conducted on the upper portion of the Nanaimo River (Table 8B). The first swim occurred on 24 September between Green Creek Junction and Old Bridge #2 where six adult and four jack chinook were enumerated; in addition, two chinook redds were located at the Green Creek Junction. The second swim occurred on 05 October between Teepee Bridge and Second Lake where 12 adult chinook, zero jack chinook, and one adult chinook mortality were enumerated. Peak counts from these two swims were included in the Nanaimo River total return calculations with 13 adult chinook and four jack chinook incorporated.

AERIAL SURVEY

One overflight was conducted on 21 October. The aircraft was piloted by Jim Valance and carried two observers, DFO Fishery Manager, Gerry Kelly and DFO Stock Assessment Technician, Lee Kearey. The primary purpose of the flight was to enumerate chum salmon in the Nanaimo River; however, the flight path was modified to also investigate the presence of chinook salmon in the Upper Nanaimo River Watershed. The areas of focus were from the South Fork Junction to the First lake outlet as well as Second lake inlet to Teepee Bridge. Due to the narrowness of the river and the height of trees only one person could conduct the counts. Weather conditions and river clarity were ideal for aerial enumeration. In the section below First Lake approximately 150 live Chinook and 50 carcasses were counted. These were all in the section between the Wolf Creek outlet and the First Lake outlet. In the section between Second Lake and Teepee Bridge three live chinook and one carcass were enumerated.

FIRST NATIONS FOOD FISHERY

There is no Snuneymuxw First Nation (SFN) fishery which specifically targets chinook salmon. However, an in-river chum gillnet fishery takes place, usually in October, to provide food fish for the SFN. The target species for this fishery is chum; however, chinook are incidentally caught and kept. This fishery is held in a one kilometer area downstream of the Cedar River Bridge and monitored by the Snuneymuxw Fisheries Guardians. In 2004, the catch

was estimated to be 220 adult chinook caught by 14 participants. No estimate for jack chinook was provided.

HATCHERY COMPONENT

During 07 October to 26 October, the Nanaimo River Hatchery's field records show approximately 48 male, 65 female, and 26 jack fall run chinook were collected from the Nanaimo River. However, the actual totals used for broodstock purposes were 107 adults and 29 jacks (Table 10). During 19 October, 27 October, and 01 November, the Nanaimo River Hatchery noted removing 11 male, three female, and 14 jack chinook from Napoleon Creek, a creek adjacent to the hatchery which is included in the Nanaimo River fall run chinook population. Officially, 12 adult and 14 jack chinook were utilized for broodstock from Napoleon Creek. Between 06 October and 12 October, 73 male, 45 female and three jack First Lake spring run chinook were recorded as being captured in the First Lake area (Table 10). Of the First Lake spring run chinook collected, official hatchery records show 59 males, 47 females, and 17 jack chinook were used in broodstock. No Upper Nanaimo River spring run chinook were removed for hatchery broodstock.

BIOLOGICAL DATA

During the lower Nanaimo River spawning ground carcass recovery 29 male, 36 female, and ten jack chinook carcasses were recovered and measured for post orbital-hypural length (Table 11A). The lengths of adult male chinook carcasses ranged from 43.8 cm to 76.8 cm and averaged 63.4 cm, while adult female carcasses ranged from 33.9 cm to 74.9 cm and averaged 65.0 cm. Jack chinook carcasses ranged in lengths from 33.2 cm to 50.2 cm and averaged 44.1 cm. A total of 11 (37.9%) male, 15 (41.7%) female, and one (10.0%) jack chinook were missing adipose fins (Table 11A). Age analysis of male chinook revealed that 29.4% were two years old, 41.2% were three years old, 26.5% were four years old, and 2.9% were five years old (Table 12A). Analysis of female chinook scales indicated that 56.7% were three years old, 30.0% were four years old, and 13.3% were five years old. All chinook were found to be ocean-type chinook fry as all scales exhibited no over-wintering in freshwater.

During the upper Nanaimo River spawning ground carcass recovery 16 male and ten female chinook carcasses were recovered and measured for post orbital-hypural length (Table 11B). The lengths of adult male chinook carcasses ranged from 51.2 cm to 85.0 cm and averaged 66.4 cm, while adult female carcasses ranged from 51.3 cm to 74.2 cm and averaged 66.3 cm. No chinook were found to have been missing an adipose fin (Table 11B). Age analysis of male chinook revealed that 53.8% were three years old and 46.2% were four years old (Table 12B). Two males (15.4%) were found to have been stream-type fry as they spent their first winter within the freshwater environment. Analysis of female chinook scales yielded that 12.5% were two years old, 62.5% were three years old, 12.5% were four years old, and 12.5% were five years old. One female was found to have been a stream-type fry as it spent one year over-wintering in freshwater.

A total of 77 male and 63 female fall run chinook were randomly collected from hatchery broodstock, measured for post orbital-hypural lengths, and examined for adipose-clipped fins (Table 13A). Male chinook ranged from 39.4 cm to 80.4 cm and averaged 54.5 cm while female chinook lengths ranged from 54.3 cm to 77.9 cm and averaged 64.2 cm. Twenty-two males (28.6%) and 27 females (42.9%) were found to be missing adipose fins (Table 13A). Fish identified as male chinook were predominately two and three years old (51.5% and 39.7%, respectively). Female chinook were mostly three and four years old (62.5% and 33.3%, respectively) (Table 14A).

A total of 47 male and 48 female First Lake spring run chinook were randomly collected from hatchery broodstock to be measured for POH lengths and monitored for the absence of adipose fins (Table 13B). Male chinook ranged from 44.5 cm to 75.0 cm and averaged 56.5 cm while female chinook ranged from 54.5 cm to 74.3 cm and averaged 65.6 cm. There were one male chinook (2.1%) and two female chinook (4.2%) missing adipose fins. Chinook identified as being males were 32.4% two years old, 54.1% three years old, and 13.5% four years old, while female chinook were 5.4% two years old, 51.4% three years old, 43.2% four years old. Two males (5.4%) and two females (5.4%) were found to have exhibited stream-type fry rearing strategies (Table 14B).

When comparing mean lengths of fall run chinook recovered from the lower Nanaimo River spawning grounds and from hatchery broodstock sampling, no statistical difference was apparent for males (combined adults and jacks) or females (Student's t-test: $t = 1.852$; $p<0.05$ and $t=0.563$, $p<0.05$, respectively). Comparisons between mean lengths of First Lake spring run chinook recovered from the upper Nanaimo River spawning grounds and chinook sampled from hatchery broodstock yielded no detectable difference for females (Student's t-test: $t = 0.343$; $p<0.05$). The same analysis was test on males; however, because broodstock collection records do not denote jack vs. adults, only males confirm to be three years or old were used in the analysis. A statistical difference was detectable in the comparison on mean lengths for adult males (Student's t-test: $t = 2.753$; $p<0.05$).

A comparison between male and female chinook mark rates obtained from lower Nanaimo River carcass mark-recapture and fall run broodstock collection did not yield a significant difference (Chi-square =0.060; $p<0.01$ and Chi-Square =0.013; $p<0.01$, for males and females, respectively). When comparing male and female chinook mark rates obtained from upper Nanaimo River carcass mark-recapture and spring run broodstock collection the difference was not significant (Chi-square =0.346; $p<0.01$ and Chi-Square =0.432; $p<0.01$, for males and females, respectively).

Twenty-eight chinook carcasses recovered on the spawning grounds were found to have been missing adipose fins with 27 of these fish containing coded-wire tags (Table 15A). Most chinook (96.3%) identified as having a CWT were reared at the Nanaimo River Hatchery, with 11 chinook (42.3%) released during the 2000 brood year, 14 chinook (53.8%) released during the 2001 brood year, and one chinook (3.8%) released during the 2002 brood year (Table 15B). One female chinook was released into the Qualicum River on 25 May 2001. A summary of the

Nanaimo River Hatchery CWT and fry release data for 1996 to 2003 brood years is presented in Table 16.

Otoliths were collected and analysed from 33 fall run and 24 First Lake spring run chinook during the course of the carcass mark-recapture study. Microscopic examination of otolith specimens revealed that one fall run chinook was released from Robertson Creek Hatchery. Scale information (European age 0.2) indicates this male chinook was released as part of the 2001 brood year strategy along with 6,407,985 other otolith marked chinook fry.

WATER MANAGEMENT PLAN

In 2004, the scheduled water release occurred between 05 October and 11 October. The target release rates from Fourth Lake were as follows: 05 October, 450 ft^3/s (12.74 m^3/s); 06 October, 450 ft^3/s (12.74 m^3/s); 07 October, 250 ft^3/s (7.08 m^3/s); 08 October, 100 ft^3/s (2.83 m^3/s); 09 October, 100 ft^3/s (2.83 m^3/s); 10 October, 100 ft^3/s (2.83 m^3/s); and 11 October, 100 ft^3/s (2.83 m^3/s). Water releases from Jump Lake were as follows: 07 October, 260 ft^3/s (7.36 m^3/s); 08 October, 120 ft^3/s (3.40 m^3/s); 09 October, 50 ft^3/s (1.42 m^3/s); 10 October, 50 ft^3/s (1.42 m^3/s); and 11 October, 50 ft^3/s (1.42 m^3/s). Daily Nanaimo River discharge is presented in Table 1 and Figure 3. A summary of mean monthly Nanaimo River discharge and ten year average is presented in Figure 4.

POPULATION ESTIMATE

The number of naturally spawning fall run adult chinook in the Nanaimo River during 2004 was determined to be the AUC swim survey estimate (1,998 fish) minus the net fall run broodstock removals (107 fish). Following this methodology, the total number of adult fall run chinook spawning in the Nanaimo River was estimated to be 1,891 fish (Table 17A). The total return of adult fall run chinook to the Nanaimo River was determined to be the sum of the AUC swim survey estimate (1,998 fish), the First Nations fishery catch (220 fish), and broodstock removals from Napoleon Creek (12 fish) , yielding 2,230 fish.

The First Lake spring run chinook estimate is derived from the aerial survey enumeration of 150 live chinook and 50 dead chinook for a spawning estimate of 200 fish. The total return estimate for First Lake spring run chinook is the spawning estimate (200 fish), plus adults used in broodstock (106 fish), yielding 306 fish. Upper Nanaimo River spring run chinook swim survey peak counts were 12 live and one dead chinook, yielding a total spring run chinook estimate of 13 fish. Therefore, the total return of fall run and spring run adult chinook to the Nanaimo River was estimated to be 2,549 fish (Table 17A).

An AUC estimate for fall run jack chinook (220 fish), minus broodstock removals from the Nanaimo River mainstem (30 fish), yielded 190 natural spawners. The total return of fall run jack chinook to the Nanaimo River was determined to be the AUC estimate (220 fish), plus broodstock removed from Napoleon Creek (14 fish), yielding 234 fish. As there was no First

Lake spring run chinook found in the carcass mark-recapture survey, the entire total run size is based on 17 jack broodstock removals. The total return for all jack chinook to the Nanaimo River was estimated to be total fall run jack chinook (234 fish), plus First Lake spring run jack chinook broodstock removals (17 fish), and upper Nanaimo River jack chinook swim survey estimates (4 fish), yielding 255 fish (Table 17B).

DISCUSSION

CARCASS MARK-RECAPTURE

A large rise in water discharge commencing on 14 November and peaking on 16 November saw an increase from 23.7 m^3/s to 112 m^3/s within a two day period (Table 1). A smaller peak occurred just at the beginning of the mark-recapture survey on 02 November (Figure 3). Flooding may have caused many carcasses to be washed out of the surveying area which would result in an underestimate of the Petersen estimates generated from the mark-recapture.

Lower Nanaimo River

Significant temporal biases for male chinook in the application samples were evident. This is likely due to the nature of the carcass recovery study, since tagging and recovery were concurrent activities. As a result, there were very few tagged carcasses available for recovery in the early period and as the number of tags in the population accumulated; tag incidence in the later periods was higher. Conversely, no temporal bias was detected in male and female chinook from the recovery samples and from the female chinook in the application samples.

No sex related bias was evident in the application or recovery samples when male and female chinook were compared or when all chinook were compared. This suggests sex was not a contributing factor in the recovery of tagged carcasses.

Size bias testing did not provide an assessment of the size selectivity of the sampling method since both application and recovery samples were attained using the same method. Rather, the size bias assessment provided an evaluation of the recoverability, based on the sizes of tagged carcasses that were redistributed back into the river after tagging. Testing revealed that there were no size biases for male, female, or jack chinook.

Upper Nanaimo River

The aerial survey conducted on 21 October observed 50 chinook carcasses as well as 150 live chinook within the upper Nanaimo River carcass mark-recapture area. The relatively low number of carcasses observed in the mark-recapture may be due to a large increase in river discharge on 02 November, one day prior to commencing the upper Nanaimo River carcass survey. Between 01 and 02 November, discharge levels increased from 49.9 m^3/s to 98.1 m^3/s

(Table 1 and Figure 3). This may have caused carcasses to be washed downstream of the survey area which could account for a lower estimate being generated through the mark-recapture.

SWIM SURVEY

Swim surveys conducted in the lower portion of the Nanaimo River provided the primary information for generating a population estimate as well as spawning distribution of fall run chinook. The last date, 15 November, used in AUC calculations assumed that no more chinook were available to be counted on or after this date. Conditions on this date were noted as having very poor visibility; however, the subsequent 19 November swim did enumerate one live chinook. Therefore, the AUC estimate did not account for a small amount of chinook within the river on or after 15 November.

The AUC estimate generated from the lower Nanaimo River swim surveys relies on an averaged survey life statistic of 17.8 days obtained from 2001 and 2002 Englishman River chinook. A tagging study to obtain the survey life statistic for Nanaimo River chinook within the lower river would increase accuracy of the population estimate.

The fall run jack chinook estimate generated by AUC calculations utilized the same observer efficiency applied to adult chinook as no specific observer efficiency was available for jacks. As jack chinook are physically smaller than most adults, jacks may be harder to see in the river and would therefore have a lower observer efficiency, resulting in increased expansions to estimates. Similarly, the survey life statistic of 17.8 days was intended for adult chinook, and therefore assumes that adult and jack chinook both are available to be counted for the same amount of time.

AERIAL SURVEY

The aerial survey provides an additional independent estimate of chinook as well as spawning distribution, especially in the upper reaches of the Nanaimo River Watershed. In the lower Nanaimo River, some misidentification is possible as chum salmon are the most abundant species in that area; however, in the upper portions of the Nanaimo River the misidentification of chinook is less likely as chum generally spawn only in lower portions of the river. Aerial estimate may include some jack chinook; however, as no jacks were recovered in the upper Nanaimo River mark-recapture survey, no adjustments were made.

FIRST NATIONS FOOD FISHERY

Catch estimation procedures developed by the Snuneymuxw First Nation have not been assessed by stock assessment staff. As a result, no comments can be made regarding the methodologies used. The 2004 estimate of 220 adult chinook is above the 1975 to 2004 average of 75.9 fish (Table 17A). Since no observers were employed during 2004, SFN catch estimates could not be independently verified.

BIOLOGICAL DATA

Both mark-recapture samples and broodstock samples collected from fall run chinook were expected to have negligible variation in lengths as they were retrieved from the same population. A comparison of female and jack mean lengths obtained from the spawning grounds and from hatchery broodstock revealed no statistical difference and conform with expected outcomes. When comparing the mean lengths of First Lake spring run chinook obtained from carcass mark-recapture and broodstock collection there was no significant difference in females; however, adult male chinook were statistically different. Adult male chinook mean lengths obtained from carcass sampling were 7.1 cm longer than those collected for hatchery broodstock. This difference may be due to a combination of factors. One factor which may bias sampling is variation in collection methods with mark-recapture obtaining dead chinook from river pools and banks, while broodstock collection employs tangle-nets and beach seines. Another factor is that smaller adult males may be more prone to getting swept downstream due to high flows experienced during the mark-recapture study.

There were no statistically significant differences in adipose fin-clip mark rates between both fall run mark-recapture and broodstock collection as well as between First Lake spring run mark-recapture and broodstock collection. This suggests that mark rate was not biased by collection method.

Coded-wire tag recoveries were primarily distributed over 2000 and 2001 brood years which correspond to three and four year old returning chinook, respectively. The lack of 2002 brood year recoveries may be in part due to the inherent bias of the carcass recapture to select for larger, older fish. Reduced CWT releases in the 2002 brood year would have also contributed to less recoveries for that specific year when compared to the previous two years. Total fall run chinook hatchery CWT fry releases for 2000 brood year were 175,664, 2001 brood year releases were 176,450, and 2002 brood year releases were 79,876 (Table 16).

WATER MANAGEMENT PLAN

In previous years, water release successes were evaluated by monitoring movement of chinook past the enumeration fence; however, this was not possible in 2004. Due to the infrequency of swim surveys, monitoring chinook movements for the purpose of evaluating the water release was not possible. Previous successes with water releases suggest that they are beneficial in aiding and encouraging chinook migration (Hop Wo et al. 2005).

POPULATION ESTIMATE

The 2004 Nanaimo River fall run chinook population estimate was based on the AUC swim survey calculation. The AUC naturally spawning estimate of 1,891 adult chinook is over five times higher than the Petersen mark-recapture estimate of 334 fish. This discrepancy may be partially due to two large increases in river discharge rates, one at the beginning of the mark-

recapture survey, the second midway through the survey. For these reasons, the AUC estimate was chosen as the most accurate population estimator for the lower Nanaimo River fall run chinook. Annual fall run adult chinook comparisons of Petersen estimates and fence counts as well as the 2004 AUC estimate are presented in Figure 6.

The First Lake chinook estimate is historically obtained by swim surveys; however, the aerial survey was chosen as the best estimator due to the absence of swim surveys in this section of the river as well as difficulties in recovering carcasses in the upper Nanaimo River. The naturally spawning estimate for First Lake adult chinook of 200 fish is below the 1995-2004 average of 373 fish. The natural spawning estimate of 1,891 fall run adult chinook is over 50% higher than the 1995-2004 average of 1,224 fish. The total return estimate for all adult chinook of 2,549 fish is also higher than the 1995-2004 average of 2,052 fish. Annual adult chinook escapements are presented in Figure 7. Annual natural and enhanced (hatchery) contributions to fall run adult chinook escapements are presented in Figure 8.

The fall run jack estimate provided by the AUC methodology cannot be compared with the mark-recapture estimate as no tagged jack carcasses were recaptured. The fall run natural spawning estimate of 190 fish is considerably lower than the 1995-2004 average of 909 fish. The total return estimate for all jack chinook within the Nanaimo River of 255 fish is also lower than the 1995-2004 average of 986 fish.

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REFERENCES

Blackman, B. 1981. Nanaimo River Stock Assessment and enhancement proposals. 35+ p. (only chinook section available for Nanaimo River Library).

Brahniuk, R., Hurst, B., and Tutty, B. 1993. Nanaimo River Salmon Management contingency plan: An overview. Discussion paper. Edited by Dr. B. Riddell, Pacific Biological Station. 20 p.

Carl, L.M. and Healey, M.C. 1984. Differences in enzyme frequency and body morphology among three juvenile life history types of chinook salmon (*Oncohynchus tshawytscha*) in Nanaimo River, British Columbia. Can J. Fish. Aquat. Sci 41: 1070–1077.

Cross, C.L., Lapi, L., and Perry, E.A. 1991. Production of chinook and coho salmon from British Columbia hatcheries, 1971 through 1989. Can. Tech. Tech. Rep. Fish. Aquat. Sci. No. 1816.

English, K.K., Bocking, R.C., and Irvine, J.R. 1992. A robust procedure for estimating salmon escapement based on the area-under-the-curve method. Can. J. Fish. Aquat. Sci. 49: 1982-1989.

Farlinger, S., Bourne, N., Riddell, B., Chalmers, D., and Tyler, A. (Eds.). 1990. Pacific stock assessment review committee (PSARC) annual report for 1989. Can. Manuscr. Rep. Fish. Aquat. Sci. 2064: 236 p.

Hardie, D.C. 2002. Chinook salmon spawning habitat survey for the Nanaimo River, 2001. Prepared for Fisheries and Oceans Canada, Science Branch, Pacific Region, Pacific Biological Station, Nanaimo, British Columbia. 13 p + maps and appendices.

Healey, M.C. 1980. Utilization of the Nanaimo River estuary by juvenile chinook salmon, *Oncorhynchus tshawytscha*. Fish. Bull. 77: 654-668.

Healey, M.C. and Jordan, F.P. 1982. Observations on juvenile chum and chinook and spawning chinook in the Nanaimo River, British Columbia, during 1975-1981. Can. Manuscr. Rep. Fish. Aquat. Sci. 1659: iv + 31 p.

Hop Wo, N.K., Nagtegaal, D.A., and Carter, E.W. 2005. The effects of water release strategies on chinook returning to the Cowichan River and the Nanaimo River. Can. Manuscr. Rep. Fish. Aquat. Sci. 2715: 107 p.

Koo, T.S.Y. 1962. Age designation in salmon, p. 41-48. In T.S.Y. Koo [ed.] Studies of Alaska red salmon. University of Washington Press, Seattle, Wash.

Ministry of Environment, Lands and Parks. 1993. Nanaimo River Water Management Plan. Water Management, Vancouver Island Regional Headquarters, Nanaimo, B.C.

Nagtegaal, D.A. and Carter, E.W. 2000. Results of rotary auger trap sampling in the Nanaimo River, 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2502: 24 p.

Parken, C.K. and Atagi, D.Y. 2000. Preliminary estimate of the escapement of summer steelhead to the Nass River, 1998. British Columbia Ministry of Environment, Lands and Parks, Smithers, BC, Skeena Fisheries Report SK-124.

PSC (Pacific Salmon Commission). 1990. Joint Chinook Technical Committee 1989 annual report. TCCHINOOK (90)-3.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382 p.

Schubert, N.D. 2000. The 1994 Stellako River sockeye (*Oncorhynchus nerka*) escapement: evaluation of pooled Petersen and stratified mark-recapture estimates of a known population. Can. Tech. Rep. Fish. Aquat. Sci. 2303: 56 p.

Shaw, W. 1994. Biological sampling manual for salmonids – A standardized approach for the Pacific Region. Can. Tech. Fish. Aquat. Sci. 1998: 167 p.

Taylor, E.B. 1990. Variability in agonistic behaviour and salinity tolerance between and within two populations of juvenile chinook salmon, *Oncorhynchus tshawytscha*, with contrasting life histories. Can. J. Fish. Aquat. Sci., vol. 47: 2172-2180.

Table 1. Nanaimo River daily discharge[1] (m^3/s) during 2004.

	Month											
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	23.0	90.2	31.6	50.7	22.1	8.81	4.36	4.10	5.89	5.56	49.9	24.9
2	20.7	65.8	28.4	39.2	24.5	8.18	4.96	4.03	5.64	5.22	98.1	22.7
3	18.6	51.5	25.1	31.2	24.6	7.48	5.14	4.11	5.35	4.98	82.8	21.5
4	16.1	43.1	23.9	28.1	23.4	7.11	4.85	4.22	5.24	4.74	61.1	46.4
5	15.3	37.8	24.5	26.8	21.2	7.04	4.61	4.11	5.05	4.67	45.9	63.2
6	17.3	44.3	23.6	26.0	18.3	7.27	4.45	4.54	4.85	5.74	39.0	54.8
7	17.9	61.1	29.1	25.9	16.4	7.50	4.13	4.77	4.70	13.4	57.5	44.8
8	30.3	59.4	49.9	25.7	14.8	7.50	3.93	4.70	4.78	34.0	70.1	66.9
9	67.5	50.5	67.6	25.3	14.2	7.46	4.41	4.49	4.88	61.1	58.7	88.5
10	142	42.1	65.0	25.6	13.9	7.12	4.77	4.30	5.22	68.1	45.4	268
11	139	36.7	51.0	27.7	13.7	6.80	4.75	4.22	12.8	51.7	36.6	387
12	114	33.3	40.2	32.5	13.4	6.26	4.68	4.21	17.4	36.7	30.5	183
13	157	31.0	33.8	33.3	13.0	7.96	4.62	4.17	17.4	28.7	23.9	101
14	369	32.2	29.9	34.6	12.7	9.41	4.54	4.12	15.1	22.6	23.7	148
15	358	37.4	27.7	34.9	12.4	9.89	4.55	4.07	15.4	18.4	87.5	151
16	208	45.0	25.6	30.4	12.2	9.48	4.48	3.98	16.1	15.6	112	101
17	116	71.3	24.4	27.6	11.6	8.43	4.38	3.84	21.2	14.0	93.0	73.9
18	90.0	87.6	29.3	24.9	11.6	8.31	4.29	3.78	29.9	16.2	90.6	64.5
19	90.5	77.9	39.2	22.5	12.3	6.50	4.23	3.78	33.7	28.0	93.0	60.7
20	82.5	63.0	38.2	24.0	12.6	5.93	4.29	3.76	27.8	41.5	74.6	53.8
21	67.9	50.6	33.3	27.6	12.9	5.48	4.29	3.91	21.9	38.0	58.3	44.6
22	56.1	41.4	30.1	26.9	13.7	5.15	4.21	4.39	17.9	33.9	47.6	34.0
23	49.2	36.1	32.1	25.8	13	4.92	4.12	4.37	14.5	31.4	40.9	29.1
24	42.5	33.1	45.1	25.1	10.9	4.79	4.2	4.42	11.9	27.5	46.0	25.9
25	39.2	38.1	84.2	23.3	9.7	4.72	4.24	5.07	9.49	32.8	67.2	24.9
26	35.7	44.1	120	21.8	10.2	4.66	4.18	6.81	8.21	62.2	64.0	27.2
27	33.4	42.5	101	23.7	10.6	4.49	4.12	7.08	7.13	60.9	51.4	28.7
28	43.2	38.5	76.6	24.2	11.5	4.33	4.11	7.01	6.50	48.0	41.0	27.4
29	59.2	35.1	59.8	22.0	10.9	4.17	4.07	6.62	6.28	38.4	34.4	26.4
30	139		55.8	20.8	9.88	4.12	4.05	6.28	5.93	51.5	27.6	26.8
31	131		59.8		9.36		4.08	6.07		51.8		26.4
Total	2789	1421	1406	838.1	441.5	201.3	136.1	145.3	368.1	957.3	1752	2347
Mean	90.0	49.0	45.3	27.9	14.2	6.71	4.39	4.69	12.27	30.9	58.4	75.7
Max	369	90.2	120	50.7	24.6	9.89	5.14	7.08	33.7	68.1	112	387
Min	15.3	31	23.6	20.8	9.36	4.12	3.93	3.76	4.7	4.67	23.7	21.5

[1] Data recorded at Water Survey Canada Station 08HB034 which is located upstream of the "Bungy Zone" in Cassidy, BC.
Discharge data is preliminary and subject to revision.

Table 2A. Daily summary of fall run chinook sampled during the carcass mark-recapture program, lower Nanaimo River, 2004.

	Carcasses Examined			Tags Applied			Recaptured Carcasses		
Date	Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
01-Nov	9	12	2	9	12	2	0	0	0
02-Nov	0	0	0	0	0	0	0	0	0
03-Nov	3	6	3	1	3	3	2	3	0
04-Nov	1	1	0	1	1	0	0	0	0
05-Nov	9	5	2	7	5	2	2	0	0
08-Nov	3	0	1	2	0	1	1	0	0
09-Nov	6	5	2	5	4	2	1	1	0
10-Nov	2	3	0	2	1	0	0	2	0
12-Nov	0	6	0	0	6	0	0	0	0
15-Nov	0	0	0	0	0	0	0	0	0
17-Nov	0	0	0	0	0	0	0	0	0
22-Nov	0	1	0	0	1	0	0	0	0
23-Nov	1	1	0	1	1	0	0	0	0
24-Nov	1	1	1	1	0	0	0	1	0
25-Nov	2	1	0	0	1	0	2	0	0
30-Nov	0	0	0	0	0	0	0	0	0
02-Dec	0	1	0	0	1	0	0	0	0
Total	37	43	11	29	36	10	8	7	0

Table 2B. Daily summary of First Lake spring run chinook sampled during the carcass mark-recapture program, upper Nanaimo River, 2004.

	Carcasses Examined			Tags Applied			Recaptured Carcasses		
Date	Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
3-Nov	2	1	0	2	1	0	0	0	0
4-Nov	0	0	0	0	0	0	0	0	0
5-Nov	6	0	0	5	0	0	1	0	0
8-Nov	1	1	0	1	1	0	0	0	0
9-Nov	2	1	0	0	1	0	2	0	0
10-Nov	0	0	0	0	0	0	0	0	0
12-Nov	4	2	0	1	2	0	3	0	0
15-Nov	0	0	0	0	0	0	0	0	0
16-Nov	0	0	0	0	0	0	0	0	0
17-Nov	4	5	0	4	4	0	0	1	0
18-Nov	2	0	0	1	0	0	1	0	0
19-Nov	0	0	0	0	0	0	0	0	0
26-Nov	1	0	0	1	0	0	0	0	0
29-Nov	0	0	0	0	0	0	0	0	0
30-Nov	1	1	0	1	1	0	0	0	0
1-Dec	0	2	0	0	0	0	0	2	0
Total	23	13	0	16	10	0	7	3	0

Table 3A. Petersen fall run chinook escapement estimates by sex, lower Nanaimo River, 2004.

Sex	Population Estimate	95% Confidence Limits	
		Lower	Upper
Male [1]	127	58	196
Female	204	83	324
Total Adult	**334**	**191**	**477**
Jack	N/A	N/A	N/A
Total Population	N/A	N/A	N/A

[1] Adult males only, jacks not included.

Table 3B. Petersen First Lake spring run chinook escapement estimates by sex, upper Nanaimo River, 2004.

Sex	Population Estimate	95% Confidence Limits	
		Lower	Upper
Male [1]	51	23	79
Female	39	9	68
Total Adult	**91**	**47**	**134**
Jack	0	-	-
Total Population	91	47	134

[1] Adult males only, jacks not included.

Table 4A. Incidence of tagged fall run adult chinook carcasses recovered on the spawning grounds by recovery period and sex, lower Nanaimo River, 2004.

Recovery Period	Days of Recovery	Tagged Recoveries			Total Recoveries			Tag Incidence (%)		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
01-Nov to 05-Nov	5	4	3	7	22	24	46	18.18	12.50	15.22
08-Nov to 12-Nov	4	2	3	5	11	14	25	18.18	21.43	20.00
15-Nov to 23-Nov	4	0	0	0	1	2	3	0.00	0.00	0.00
24-Nov to 02-Dec	4	2	1	3	3	3	6	66.67	33.33	50.00
Total	17	8	7	15	37	43	80	21.62	16.28	18.75
Chi-square test result:								4.10	1.55	
Critical Chi-square (df = 3; alpha = 0.01)								11.35	11.35	

Table 4B. Incidence of tagged First Lake spring run adult chinook carcasses recovered on the spawning grounds by recovery period and sex, upper Nanaimo River, 2004.

Recovery Period	Days of Recovery	Tagged Recoveries			Total Recoveries			Tag Incidence (%)		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
03-Nov to 10-Nov	6	3	0	3	11	3	14	27.27	0.00	21.43
12-Nov to 19-Nov	6	4	1	5	10	7	17	40.00	14.29	29.41
26-Nov to 01-Dec	4	0	2	2	2	3	5	0.00	66.67	40.00
Total	16	7	3	10	23	13	36	30.43	23.08	27.78

Table 5A. Percentage of the tag application sample recovered on the spawning grounds by application period and sex, lower Nanaimo River, 2004.

Application Period	Days of Application	Tags Applied			Tagged Recoveries			Percent Recovered		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
01-Nov to 05-Nov	5	18	21	39	4	3	7	22.22	14.29	17.95
08-Nov to 12-Nov	4	9	11	20	2	3	5	22.22	27.27	25.00
15-Nov to 23-Nov	4	1	2	3	0	0	0	0.00	0.00	0.00
24-Nov to 02-Dec	4	1	2	3	2	1	3	200.00	50.00	100.00
Total	17	29	36	65	8	7	15	27.59	19.44	23.08
Chi-square test result:								15.65	2.46	
Critical Chi-square (df = 3; alpha = 0.01)								11.35	11.35	

Table 5B. Percentage of the tag application sample recovered on the spawning grounds by application period and sex, upper Nanaimo River, 2004.

Application Period	Days of Application	Tags Applied			Tagged Recoveries			Percent Recovered		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
03-Nov to 10-Nov	6	8	3	11	3	0	3	37.50	0.00	27.27
12-Nov to 19-Nov	6	6	6	12	4	1	5	66.67	16.67	41.67
26-Nov to 01-Dec	4	2	1	3	0	2	2	0.00	200.00	66.67
Total	16	16	10	26	7	3	10	43.75	30.00	38.46

Table 6A. Sex composition of fall run chinook in the tag application and recovery samples, lower Nanaimo River, 2004.

	Application sample by recovery status				Recovery sample by mark status			
Sex	Sample Size	Recovered	Not Recovered	Total	Sample Size	Marked	Not Marked	Total
Male	29	53.3%	42.0%	44.6%	37	53.3%	44.6%	46.3%
Female	36	46.7%	58.0%	55.4%	43	46.7%	55.4%	53.8%
Chi-square test result:				0.60				0.37
Critical Chi-square (df = 1; alpha = 0.01)				6.64				6.64

Table 6B. Sex composition of First Lake spring run chinook in the tag application and recovery samples, upper Nanaimo River, 2004.

	Application sample by recovery status				Recovery sample by mark status			
Sex	Sample Size	Recovered	Not Recovered	Total	Sample Size	Marked	Not Marked	Total
Male	16	70.0%	56.3%	61.5%	23	70.0%	61.5%	63.9%
Female	10	30.0%	43.8%	38.5%	13	30.0%	38.5%	36.1%

Table 7. Sex composition of fall run chinook in the tag application and recovery samples, lower Nanaimo River, 2004 (jacks included).

	Application sample by recovery status				Recovery sample by mark status			
Sex	Sample Size	Recovered	Not Recovered	Total	Sample Size	Marked	Not Marked	Total
Male	29	53.3%	35.0%	38.7%	37	53.3%	38.2%	40.7%
Female	36	46.7%	48.3%	48.0%	43	46.7%	47.4%	47.3%
Jack	10	0.0%	16.7%	13.3%	11	0.0%	14.5%	12.1%
Chi-square test result:				3.55				2.88
Critical Chi-square (df = 2; alpha = 0.01)				9.21				9.21

Table 8A. Swim surveys conducted on the lower Nanaimo River, 2004.

Date	Segment 1				Segment 2				Segment 3				Segment 4				Segment Totals				Comments
	Co	Cm	Cn	Cn J	Co	Cm	Cn	Cn J	Co	Cm	Cn	Cn J	Co	Cm	Cn	Cn J	Co	Cm	Cn	Cn J	
09-Sep					0	0	16	2	0	0	2	0	0	0	568	0	0	0	586	2	Seg. 3: spot checks in 3 pools.
16-Sep	2	0	68	1	0	0	280	0	0	0	1	0	2	5	52	0	4	5	401	1	
23-Sep	0	1	175	58	20	8	169	34	0	0	0	0					20	9	344	92	
30-Sep	10	11	101	79	62	24	375	89	1	42	49	8	314	2,015	174	0	387	2,092	699	176	
08-Oct	2	35	62	6	combined with Seg. 3				25	450	84	3	5	1,196	2	0	32	1,681	148	9	Poor visibility.
14-Oct	34	225	171	17	81	771	117	18	115	996	288	35					230	1,992	576	70	
21-Oct	24	277	35	2	139	1,439	41	8	25	5,275	8	1					188	6,991	84	11	
28-Oct	41	661	32	4	86	1,756	8	0	7	6,674	0	0					134	9,091	40	4	
04-Nov	25	235	4	4	108	887	9	0	5	4,321	1	1					138	5,443	14	5	
15-Nov	1	9	0	0	6	21	0	0	0	7	0	0					7	37	0	0	Very poor visibility.
19-Nov	36	6	0	0	39	72	1	0	16	149	0	0					91	227	1	0	

Location Descriptions (see Figure 2)
Segment 1: Bridge Pool to Alder Run.
Segment 2: Haslam Creek Junction to House Pool.
Segment 3: Maffeo Side Channel to Cedar Firehall.
Segment 4: Barn Hole to Raines Road Pool (650m downstream of Cedar Bridge).

Table 8B. Swim surveys conducted on the upper Nanaimo River, 2004.

Upper Nanaimo River Spring Run Chinook		Chinook		
Date	Area	Adult	Jack	Comments
24-Sep	Green Creek to Old Bridge #2	6	4	2 chinook redds at Green Creek junction.
05-Oct	Teepee Bridge to Second Lake	12	0	1 adult mortality.

Table 9A. Swim survey counts for adult chinook with observer efficiency, percent coverage, and system estimate conducted on the lower Nanaimo River, 2004.

Swim Date	Chinook Counts	Observer Efficiency	Expanded Counts	Percent Coverage	System Estimate	Comments
20-Aug	0	100%	0	-	0	Estimate provide by H. Bob, Nanaimo River Hatchery Co-Manager.
09-Sep	586	90%	651	75%	868	
16-Sep	401	90%	446	100%	446	
23-Sep	455	95%	479	75%	639	
30-Sep	699	95%	736	100%	736	
08-Oct	148	75%	-	100%	-	Poor visibility not used in AUC calculation.
14-Oct	576	95%	606	95%	673	System estimate adjusted for broodstock removals.
21-Oct	84	85%	99	95%	121	System estimate adjusted for broodstock removals.
28-Oct	40	80%	50	95%	62	System estimate adjusted for broodstock removals.
04-Nov	14	85%	16	95%	20	System estimate adjusted for broodstock removals.
15-Nov	0	70%	0	75%	0	Very poor visiblity but will use this as the end zero count for chinook.
19-Nov	1	100%	1	100%	-	Not included in AUC calculation.

Table 9B. Swim survey counts for jack chinook with observer efficiency, percent coverage, and system estimate conducted on the lower Nanaimo River, 2004.

Swim Date	Chinook Counts	Observer Efficiency	Expanded Counts	Percent Coverage	System Estimate	Comments
20-Aug	0	100%	0	-	0	Estimate provide by H. Bob, Nanaimo River Hatchery Co-Manager.
09-Sep	2	90%	2	75%	3	
16-Sep	1	90%	1	100%	1	
23-Sep	94	95%	99	75%	132	
30-Sep	176	95%	185	100%	185	
08-Oct	9	75%	-	100%	-	Poor visibility not used in AUC calculation.
14-Oct	70	95%	74	95%	78	
21-Oct	11	85%	13	95%	14	
28-Oct	4	80%	5	95%	5	
04-Nov	5	85%	6	95%	6	
15-Nov	0	70%	0	75%	0	Very poor visiblity but will use this as the end zero count for chinook.
19-Nov	0	100%	0	100%	-	Not included in AUC calculation.

Table 10. Summary by day and location of chinook collected for Nanaimo River Hatchery broodstock, 2004.

Fall Run Chinook Date (dd/mmm)	Location Code[1]	Chinook Male	Female	Jack
07-Oct	22	18	9	0
08-Oct	22	2	14	6
12-Oct	22	7	6	5
13-Oct	22	10	8	2
14-Oct	22	2	6	0
15-Oct	20-11	5	8	3
18-Oct	22	1	6	3
19-Oct	22	1	6	5
20-Oct	22	1	0	1
26-Oct	19	1	1	0
26-Oct	11	0	1	1
Total		**48**	**65**	**26**
Spawning Total [2]		**107 (males and females combined)**		**29**

Fall Run Chinook Date (dd/mmm)	Location Code[1]	Chinook Male	Female	Jack
19-Oct	Napoleon Creek	8	1	10
27-Oct	Napoleon Creek	3	1	2
01-Nov	Napoleon Creek	0	1	2
Total		**11**	**3**	**14**
Spawning Total [2]		**12 (males and females combined)**		**14**

Spring Run Chinook Date (dd/mmm)	Location	Chinook Male	Female	Jack
06-Oct	First Lake	59	21	1
07-Oct	First Lake	10	2	0
08-Oct	First Lake	3	21	2
12-Oct	First Lake	1	1	0
Total		**73**	**45**	**3**
Spawning Total [2]		**59**	**47**	**17**

[1] See Figure 1.

[2] Spawning Total obtained from hatchery spawning records and may differ slightly from field records.

Table 11A. Length-frequency of fall run chinook sampled during the carcass mark-recapture program, lower Nanaimo River, 2004.

Length (cm)	Males	Females	Jacks
33	0	0	1
34	0	1	0
35	0	0	0
36	0	0	0
37	0	0	0
38	0	0	0
39	0	0	0
40	0	0	0
41	0	0	1
42	0	0	0
43	0	0	1
44	1	0	3
45	0	0	1
46	0	0	0
47	0	0	1
48	0	0	0
49	0	0	1
50	0	0	1
51	2	0	0
52	0	0	0
53	0	0	0
54	3	0	0
55	0	1	0
56	0	0	0
57	1	0	0
58	2	1	0
59	2	1	0
60	0	2	0
61	1	2	0
62	2	3	0
63	1	2	0
64	0	2	0
65	1	5	0
66	1	0	0
67	2	2	0
68	2	0	0
69	1	3	0
70	0	3	0
71	0	3	0
72	1	2	0
73	1	2	0
74	2	0	0
75	1	1	0

Table 11A. (continued)

Length (cm)	Males	Females	Jacks
76	1	0	0
77	1	0	0
Total	29	36	10
Mean Length (cm)	63.4	65.0	44.1
Std. Deviation	8.6	7.3	4.7
Adipose Clips	11	15	1
Mark Rate	37.9%	41.7%	10.0%

Table 11B. Length-frequency of First Lake spring run chinook sampled during the carcass mark-recapture program, upper Nanaimo River, 2004.

Length (cm)	Males	Females
51	1	1
52	0	0
53	0	0
54	0	0
55	0	0
56	0	1
57	1	0
58	1	0
59	3	0
60	1	0
61	0	0
62	0	0
63	0	0
64	1	0
65	1	2
66	0	0
67	0	0
68	0	0
69	0	2
70	1	1
71	0	1
72	1	1
73	2	0
74	0	1
75	0	0
76	0	0
77	0	0
78	1	0
79	1	0
80	0	0
81	0	0
82	0	0
83	0	0
84	0	0
85	1	0
Total	16	10
Mean Length (cm)	66.4	66.3
Std. Deviation	9.5	7.4
Adipose Clips	0	0
Mark Rate	0.0%	0.0%

Table 12A. Summary of age data from fall run chinook sampled during the carcass mark-recapture program, lower Nanaimo River, 2004.

European Age [1]	Brood Year	Total Age	Males		Females		Adult Total	
			#	%	#	%	#	%
0.1	2002	2	10	29.4%	0	0.0%	10	15.6%
0.2	2001	3	14	41.2%	17	56.7%	31	48.4%
0.3	2000	4	9	26.5%	9	30.0%	18	28.1%
0.4	1999	5	1	2.9%	4	13.3%	5	7.8%
Total			34	1.0	30	1.0	64	1.0

[1] The first number indicates the number of annuli formed in freshwater, the second number indicates the number of annuli formed in the ocean (Koo 1962).

Total number of unreadable scales: 11

Table 12B. Summary of age data from First Lake spring run chinook sampled during the carcass mark-recapture program, upper Nanaimo River, 2004.

European Age [1]	Brood Year	Total Age	Males		Females		Adult Total	
			#	%	#	%	#	%
0.1	2002	2	0	0.0%	1	12.5%	1	4.8%
0.2	2001	3	6	46.2%	4	50.0%	10	47.6%
1.1	2001	3	1	7.7%	1	12.5%	2	9.5%
0.3	2000	4	5	38.5%	1	12.5%	6	28.6%
1.2	2000	4	1	7.7%	0	0.0%	1	4.8%
0.4	1999	5	0	0.0%	1	12.5%	1	4.8%
Total			13	1.0	8	1.0	21	1.0

[1] The first number indicates the number of annuli formed in freshwater, the second number indicates the number of annuli formed in the ocean (Koo 1962).

Total number of unreadable scales: 5

Table 13A. Length-frequency of fall run chinook sampled during broodstock collection, lower Nanaimo River, 2004.

Length (cm)	Males	Females
39	1	0
40	1	0
41	2	0
42	4	0
43	4	0
44	2	0
45	2	0
46	5	0
47	4	0
48	4	0
49	1	0
50	4	0
51	1	0
52	3	0
53	2	0
54	1	1
55	0	1
56	2	1
57	2	2
58	1	3
59	5	6
60	2	6
61	5	4
62	3	2
63	2	2
64	2	5
65	1	5
66	1	5
67	2	4
68	1	4
69	1	3
70	1	1
71	1	1
72	0	0
73	0	2
74	0	0
75	0	2
76	0	1
77	0	1

Table 13A. (continued)

Length (cm)	Males	Females
78	2	1
79	1	0
80	1	0
Total	77	63
Mean Length (cm)	54.5	64.2
Std. Deviation	10.2	5.6
Adipose Clips	22	27
Mark Rate	28.6%	42.9%

Table 13B. Length-frequency of First lake spring run chinook sampled during broodstock collection, Nanaimo River, 2004.

Length (cm)	Males	Females
45	3	0
46	1	0
47	2	0
48	0	0
49	0	0
50	7	0
51	3	0
52	0	0
53	4	0
54	3	0
55	2	2
56	0	3
57	1	2
58	2	0
59	2	1
60	1	1
61	5	1
62	1	1
63	0	2
64	0	1
65	2	6
66	2	4
67	0	2
68	2	4
69	2	7
70	0	4
71	0	0
72	1	5
73	0	0
74	0	2
75	1	0
Total	47	48
Mean Length (cm)	56.5	65.6
Std. Deviation	7.7	5.3
Adipose Clips	1	2
Mark Rate	2.1%	4.2%

Table 14A. Summary of age data from fall run chinook broodstock collection, lower Nanaimo River, 2004.

European Age [1]	Brood Year	Total Age	Males		Females		Total	
			#	%	#	%	#	%
0.1	2002	2	35	51.5%	0	0.0%	35	30.2%
0.2	2001	3	27	39.7%	30	62.5%	57	49.1%
0.3	2000	4	4	5.9%	15	31.3%	19	16.4%
1.2	2000	4	0	0.0%	1	2.1%	1	0.9%
0.4	1999	5	2	2.9%	2	4.2%	4	3.4%
Total			68	1	48	1	116	1

[1] The first number indicates the number of annuli formed in freshwater, the second number indicates the number of annuli formed in the ocean (Koo 1962).

Total number of unreadable scales: 23

Table 14B. Summary of age data from First Lake spring run chinook broodstock collection, upper Nanaimo River, 2004.

European Age [1]	Brood Year	Total Age	Males		Females		Total	
			#	%	#	%	#	%
0.1	2002	2	12	32.4%	2	5.4%	14	18.9%
0.2	2001	3	20	54.1%	19	51.4%	39	52.7%
0.3	2000	4	3	8.1%	14	37.8%	17	23.0%
1.2	2000	4	2	5.4%	2	5.4%	4	5.4%
Total			37	1.0	37	1.0	74	1.0

[1] The first number indicates the number of annuli formed in freshwater, the second number indicates the number of annuli formed in the ocean (Koo 1962).

Total number of unreadable scales: 21

Table 15A. Coded-wire tag data from chinook sampled on the spawning grounds, lower Nanaimo River, 2004.

Recovery Data					Release Data				
Date (dd/mmm)	Loc.[1]	Adipose Status[2]	POH Length (mm)	Sex	Brood Year	Tag Code	Location	Start Release Date (dd/mmm/yy)	End Release Date (dd/mmm/yy)
01-Nov	18	A	768	M	2000	18-45-52	Nanaimo R	28-Apr-01	29-May-01
01-Nov	18	A	747	M	2000	18-45-53	Nanaimo R	28-Apr-01	29-May-01
01-Nov	18	A	651	F	2000	18-45-54	Hatchery	28-Apr-01	29-May-01
01-Nov	18	A	729	F	2000	18-45-54	Hatchery	28-Apr-01	29-May-01
01-Nov	18	A	436	J	2002	18-55-27	Nanaimo R	31-Jul-03	31-Jul-03
01-Nov	18	A	706	F		No Pin			
03-Nov	14	A	646	F	2001	18-32-06	Nanaimo R	14-May-02	14-May-02
03-Nov	11	A	672	M	2001	18-46-28	Jack Point	17-May-02	17-May-02
03-Nov	13	A	703	F	2001	18-47-18	Nanaimo R	09-May-02	09-May-02
04-Nov	10	A	597	F	2001	18-32-06	Nanaimo R	14-May-02	14-May-02
05-Nov	13	A	741	M	2000	18-45-52	Nanaimo R	28-Apr-01	29-May-01
05-Nov	19	A	731	F	2000	18-45-52	Nanaimo R	28-Apr-01	29-May-01
05-Nov	7	A	729	M	2000	18-45-53	Nanaimo R	28-Apr-01	29-May-01
05-Nov	7	A	633	M	2001	18-46-28	Jack Point	17-May-02	17-May-02
05-Nov	13	A	512	M	2001	18-47-17	Nanaimo R	09-May-02	09-May-02
05-Nov	13	A	611	M	2001	18-47-18	Nanaimo R	09-May-02	09-May-02
08-Nov	10	A	585	M	2001	18-47-18	Nanaimo R	09-May-02	09-May-02
09-Nov	12	A	649	F	2000	18-45-52	Nanaimo R	28-Apr-01	29-May-01
09-Nov	12	A	716	M	2000	18-45-53	Nanaimo R	28-Apr-01	29-May-01
09-Nov	13	A	638	F	2001	18-47-15	Nanaimo R	16-May-02	16-May-02
09-Nov	9	A	438	M	2001	18-47-16	Nanaimo R	16-May-02	16-May-02
09-Nov	13	A	546	F	2001	18-47-18	Nanaimo R	09-May-02	09-May-02
10-Nov	15	A	683	M	2000	18-45-52	Nanaimo R	28-Apr-01	29-May-01
12-Nov	6	A	611	F	2001	18-32-06	Nanaimo R	14-May-02	14-May-02
12-Nov	18	A	721	F	2000	18-43-43	Qualicum R	25-May-01	30-May-01
12-Nov	13	A	616	F	2001	18-47-16	Nanaimo R	16-May-02	16-May-02
12-Nov	18	A	645	F	2001	18-47-16	Nanaimo R	16-May-02	16-May-02
22-Nov	14	A	712	F	2000	18-45-53	Nanaimo R	28-Apr-01	29-May-01

[1] See Figure 2. [2] A = Absent Adipose; P = Present Adipose.

Table 15B. Summary of coded-wire tag data from chinook sampled on the spawning grounds by releasing hatchery and by brood year, lower Nanaimo River, 2004.

Release Location	Brood Year 2000	2001	2002	Total
Nanaimo River Hatchery				
Hatchery	2	0	0	2
Jack Point	0	2	0	2
Nanaimo R	9	12	1	22
Total	11	14	1	26
Little Qualicum River Hatchery				
Qualicum R	1	0	0	1
Grand Total	12	14	1	27

Table 16. Nanaimo River Hatchery chinook release data for brood years 1996 - 2003.

Tagcode	Brood Year	Number Tagged	Number Released	CWT % Marked	Weight (g)	Start Release Date	End Release Date	Release Site	Run Type
182747	1996	28,525	115,033	24.8	5.44	05/05/1997	05/05/1997	Nanaimo R.	Fall
182306	1996	9,132	36,827	24.8	5.44	05/05/1997	05/05/1997	Nanaimo R.	Fall
183454	1996	10,095	42,937	23.51	6.22	20/05/1997	20/05/1997	First Lake	Spring
183453	1996	10,077	42,861	23.51	6.22	20/05/1997	20/05/1997	First Lake	Spring
183452	1996	10,052	42,755	23.51	6.22	20/05/1997	20/05/1997	First Lake	Spring
183455	1996	10,050	42,746	23.51	6.22	20/05/1997	20/05/1997	First Lake	Spring
181716	1996	10,025	83,484	12.01	4.94	20/05/1997	21/05/1997	Nanaimo R.	Fall
182746	1996	27,690	230,592	12.01	4.94	20/05/1997	21/05/1997	Nanaimo R.	Fall
183220	1997	25,240	70,000	36.06	6.67	07/05/1998	07/05/1998	First Lake	Spring
183221	1997	25,173	99,098	25.4	6	15/05/1998	15/05/1998	First Lake	Spring
183223	1997	28,252	43,881	64.38	6.01	26/05/1998	26/05/1998	Nanaimo R.	Fall
182408	1997	10,050	15,610	64.38	6.01	26/05/1998	26/05/1998	Nanaimo R.	Fall
183222	1997	24,824	24,824	100	15.5	23/07/1998	23/07/1998	Jack Point	Fall
-	1998	0	442,830	0	5.1	12/05/1999	13/05/1999	Nanaimo R.	Fall
-	1998	0	165,595	0	5.61	28/05/1999	28/05/1999	First Lake	Spring
-	1998	0	50,411	0	11	02/06/1999	08/07/1999	Jack Point	Fall
184330	1999	25,185	257,394	9.78	4.03	17/05/2000	17/05/2000	First Lake	Spring
184332	1999	25,071	25,071	100	5.1	18/05/2000	18/05/2000	Nanaimo R.	Fall
184331	1999	25,185	25,185	100	5.1	18/05/2000	18/05/2000	Nanaimo R.	Fall
184333	1999	25,165	25,165	100	5.1	18/05/2000	18/05/2000	Nanaimo R.	Fall
184334	1999	25,231	25,231	100	5.1	18/05/2000	18/05/2000	Nanaimo R.	Fall
-	1999	0	99,238	0	4.8	18/05/2000	18/05/2000	Nanaimo R.	Fall
184335	1999	25,300	126,422	20.01	5	05/05/2000	23/05/2000	Nanaimo R.	Fall
184336	1999	25,115	125,497	20.01	5	05/05/2000	23/05/2000	Nanaimo R.	Fall
184329	1999	25,175	57,625	43.69	10.34	23/06/2000	23/06/2000	Jack Point	Fall
184363	2000	24,739	207,955	11.9	6.56	23/05/2001	24/05/2001	First Lake	Spring
184552	2000	50,060	105,512	47.44	4.9	28/04/2001	29/05/2001	Nanaimo R.	Fall
184554	2000	50,259	105,931	47.45	4.9	28/04/2001	29/05/2001	Nanaimo R.	Fall
184553	2000	50,254	105,920	47.45	4.9	28/04/2001	29/05/2001	Nanaimo R.	Fall
184362	2000	25,091	51,070	49.13	8.67	06/06/2001	06/06/2001	Jack Point	Fall
184717	2001	25,119	102,917	24.41	4.68	09/05/2002	09/05/2002	Nanaimo R.	Fall
184718	2001	25,355	103,883	24.41	4.68	09/05/2002	09/05/2002	Nanaimo R.	Fall
183205	2001	25,182	25,182	100	5.61	14/05/2002	14/05/2002	Nanaimo R.	Fall
183206	2001	25,237	25,237	100	5.61	14/05/2002	14/05/2002	Nanaimo R.	Fall
184337	2001	25,102	186,187	13.48	5.7	16/05/2002	16/05/2002	First Lake	Spring
184715	2001	25,307	25,307	100	3.78	16/05/2002	16/05/2002	Nanaimo R.	Fall
184716	2001	25,131	25,131	100	3.78	16/05/2002	16/05/2002	Nanaimo R.	Fall
184628	2001	25,119	51,508	48.77	6.62	17/05/2002	17/05/2002	Jack Point	Fall
185527	2002	39,650	39,650	100	20	31/07/2003	31/07/2003	Nanaimo R.	Fall
185528	2002	40,226	40,226	100	10	31/05/2003	31/05/2003	Nanaimo R.	Fall
-	2002	0	173,081	0	7.17	06/05/2003	19/05/2003	First Lake	Spring
-	2002	0	324,204	0	6	08/05/2003	21/05/2003	Nanaimo R.	Fall
-	2003	0	187,214	0	6.93	18/05/2004	18/05/2004	First Lake	Spring
-	2003	0	120,199	0	4.86	19/05/2004	19/05/2004	Nanaimo R.	Fall

Table 17A. Total adult chinook returns to the Nanaimo River, 1975-2004.

	Natural Spawners		Hatchery Broodstock		First Nations	Total
Year	Fall	Spring[1]	Fall	Spring[1]	Food Fish Catch	Returns
1975	475	-	-	-	15	490
1976	880	-	-	-	50	930
1977	2380	-	-	-	60	2420
1978	2125	-	-	-	40	2165
1979	2700	-	41	-	23	2764
1980	2900	-	82	-	200	3182
1981	210	-	15	-	100	325
1982	1090	-	62	-	21	1173
1983	1600	-	240	-	30	1870
1984	3000	-	178	-	50	3228
1985	650	-	264	-	185	1099
1986	700	-	258	-	190	1148
1987	400	-	357	-	50	807
1988	650	-	429	-	0	1079
1989	1150	-	402	-	0	1552
1990	1275	-	122	-	0	1397
1991	800	-	135	-	0	935
1992	800	-	377	-	0	1177
1993	850	-	528	-	0	1378
1994	400	-	280	-	10	752
1995	1592[2]	100	311	75	50	2128[3]
1996	990[2]	600	257	167	335	2349[3]
1997	638[2]	600	52	129	0	1419[3]
1998	1011[2]	200	251	89	0	1551[3]
1999	1920[4]	500	242	179	70	2911[3]
2000	596[6]	450	184	162	126	1518[3]
2001	1277[6]	250	165	169	188	2049[3]
2002	946[6]	432	212	205	213	2008[3]
2003	1378[7]	393	82[8]	131[8]	50	2034[3]
2004	1891[9]	200	119[10]	106	220	2549[11]

[1] Ocean type only.

[2] Count at enumeration fence minus broodstock removal above the fence.

[3] Fall natural spawners plus fall broodstock removal below the fence, Native food fish catch and spring run estimate.

[4] Mark recapture Peterson estimate.

[5] Mark recapture estimate plus fall broodstock removal, Native food fish catch and spring run estimate.

[6] Adjusted fence count minus broodstock removal above the fence.

[7] Extrapolated fence count, plus adult/jack adjustment, minus broodstock removals above the fence.

[8] Does not include fish released during highwater.

[9] AUC estimate minus broodstock removals

[10] 107 fish from Nanaimo River Mainstem and 12 from Napoleon Creek.

[11] AUC estimate plus spring estimates plus Native food fish catch.

Table 17B. Total jack chinook returns to the Nanaimo River, 1998-2004.

	Natural Spawners		Hatchery Broodstock		First Nations	Total
Year	Fall [1]	Spring [2]	Fall	Spring [1]	Food Fish Catch	Returns [3]
1995	3236	200	88	N/A	-	3524
1996	891	-	72	28	-	991
1997	173	-	24	12	-	209
1998	599	-	30	6	-	635
1999	280 [4]	-	3	21	-	304 [5]
2000	992	-	10	6	-	1008
2001	1385 [6]	-	19	27	-	1431
2002	644 [6]	-	15	15	-	674
2003	772 [7]	-	48	8	-	828
2004	190 [8]	-	30	17	-	255

[1] Count at enumeration fence minus broodstock removal above the fence.

[2] First Lake spring run only.

[3] Natural spawners plus fall broodstock removal below the fence, Native food fish catch and spring run estimate.

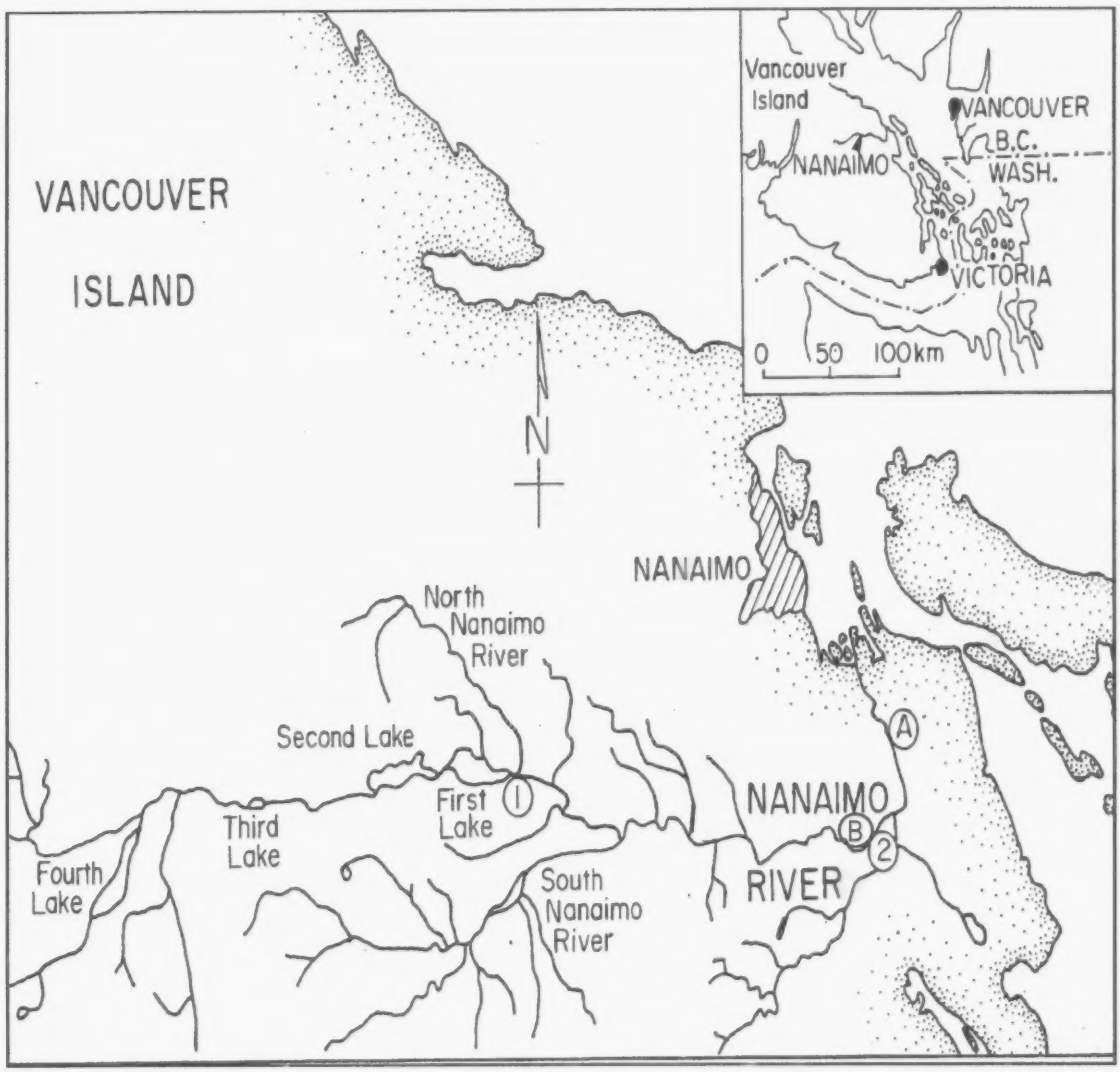
[4] Mark recapture Peterson estimate.

[5] Mark recapture estimate plus fall broodstock removal, Native food fish catch and spring run estimate.

[6] Adjusted fence count minus broodstock removal above the fence.

[7] Extrapolated fence count, plus adult/jack adjustment, minus broodstock removals above the fence.

[8] AUC estimate minus broodstock removals.



LEGEND:

1	Hatchery Release Site
2	Hatchery Release Site
A	Enumeration Fence Site (removed 2003)
B	Downstream Fry Trapping Site

Figure 1. Nanaimo River study area.

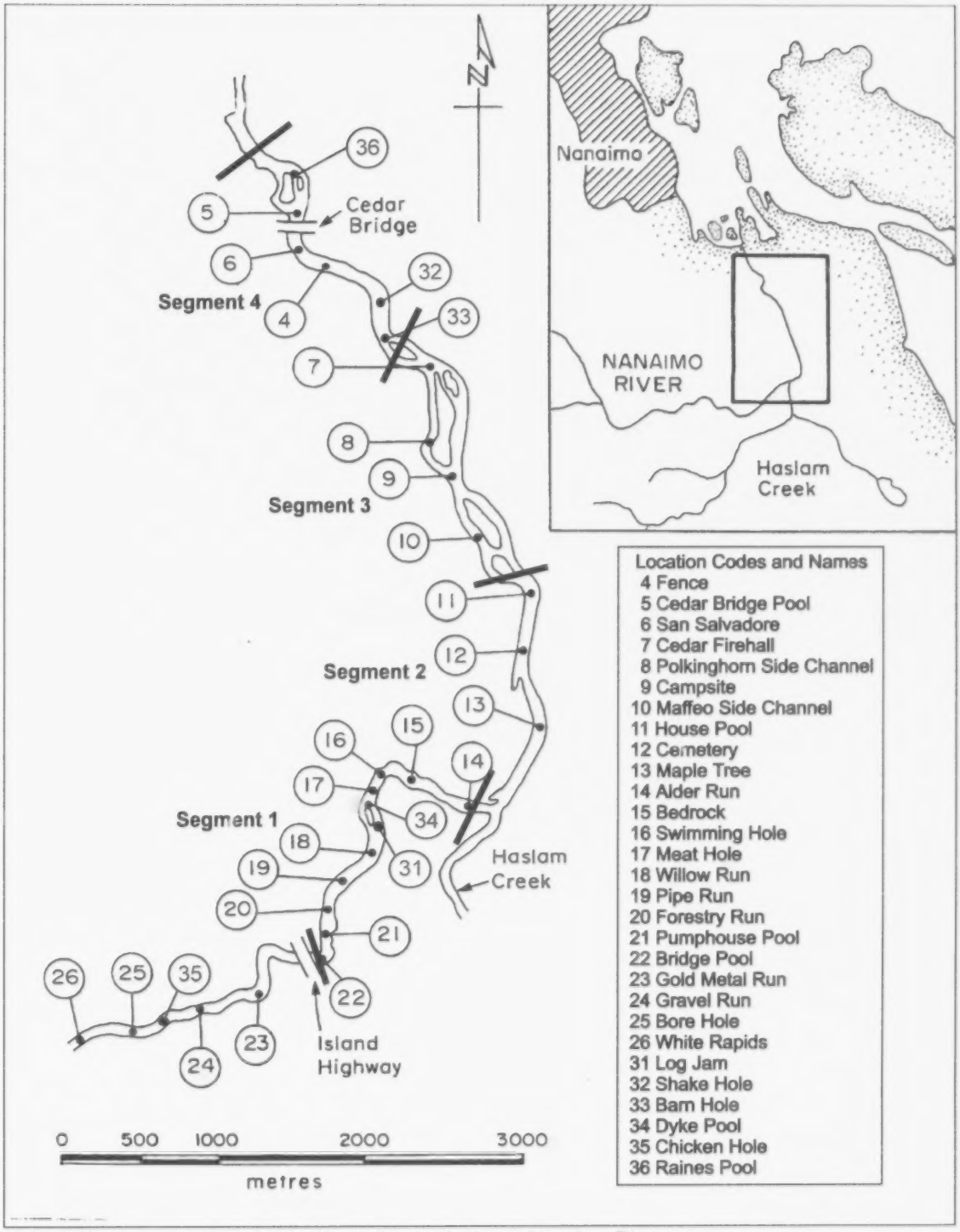


Figure 2. Swim survey and mark-recapture sites on the lower Nanaimo River.

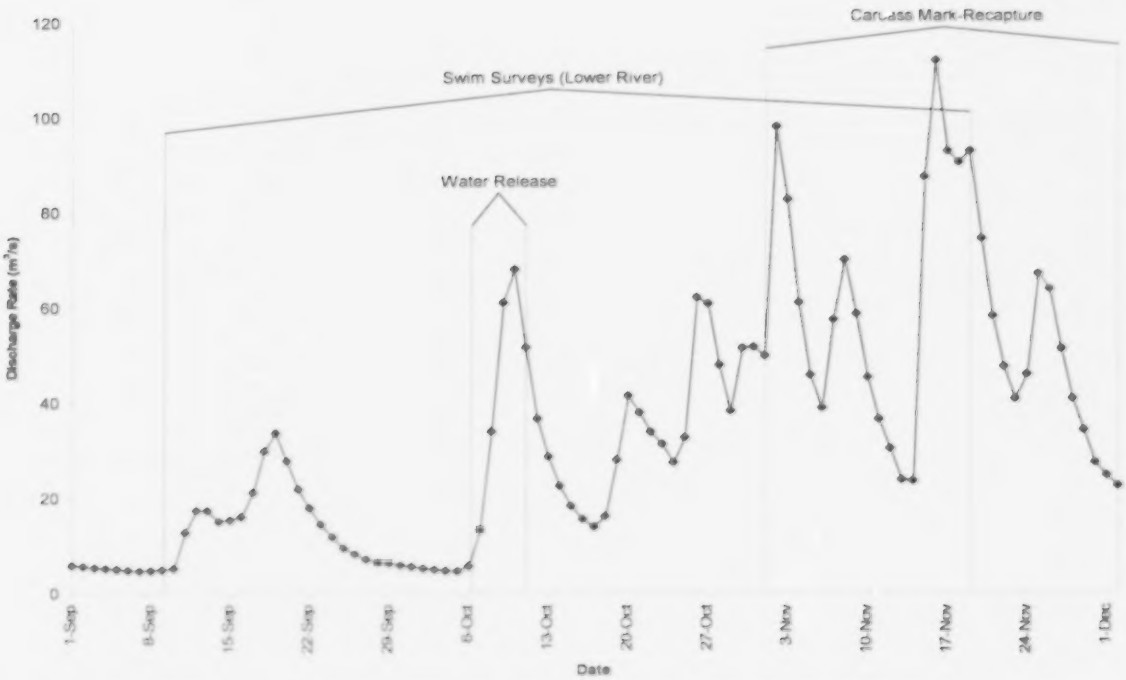


Figure 3. Daily Nanaimo River Discharge (m^3/s) during the fall run chinook season, 2004.
Discharge data is preliminary and subject to revision.

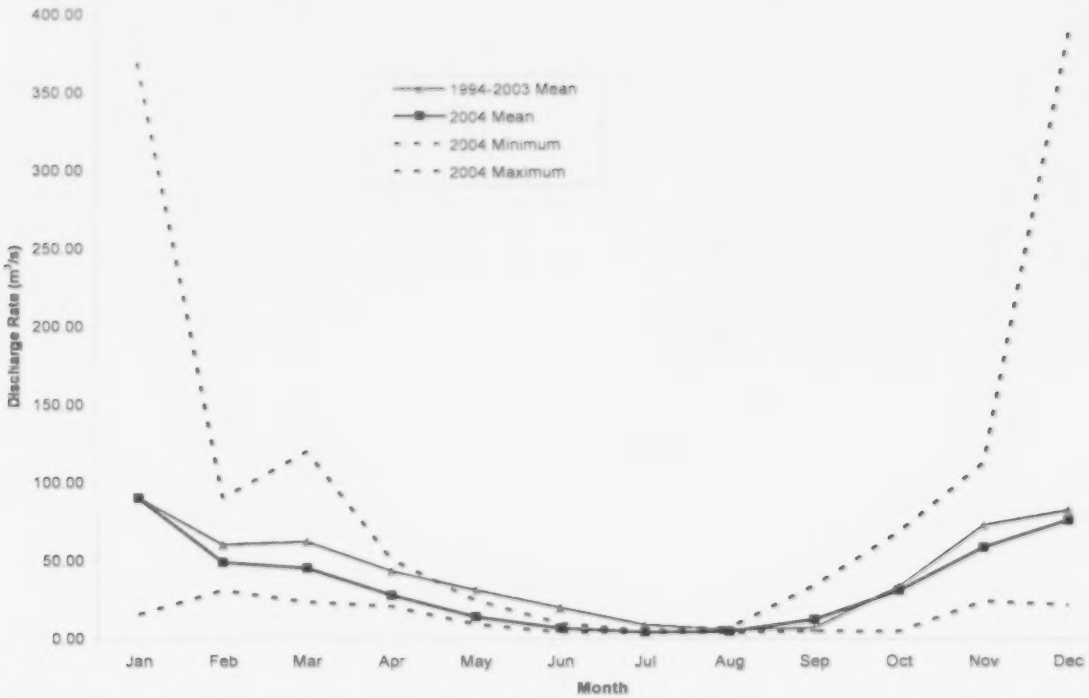


Figure 4. Monthly Nanaimo River discharge (m^3/s) in 2004 along with ten year mean.
Discharge data is preliminary and subject to revision.

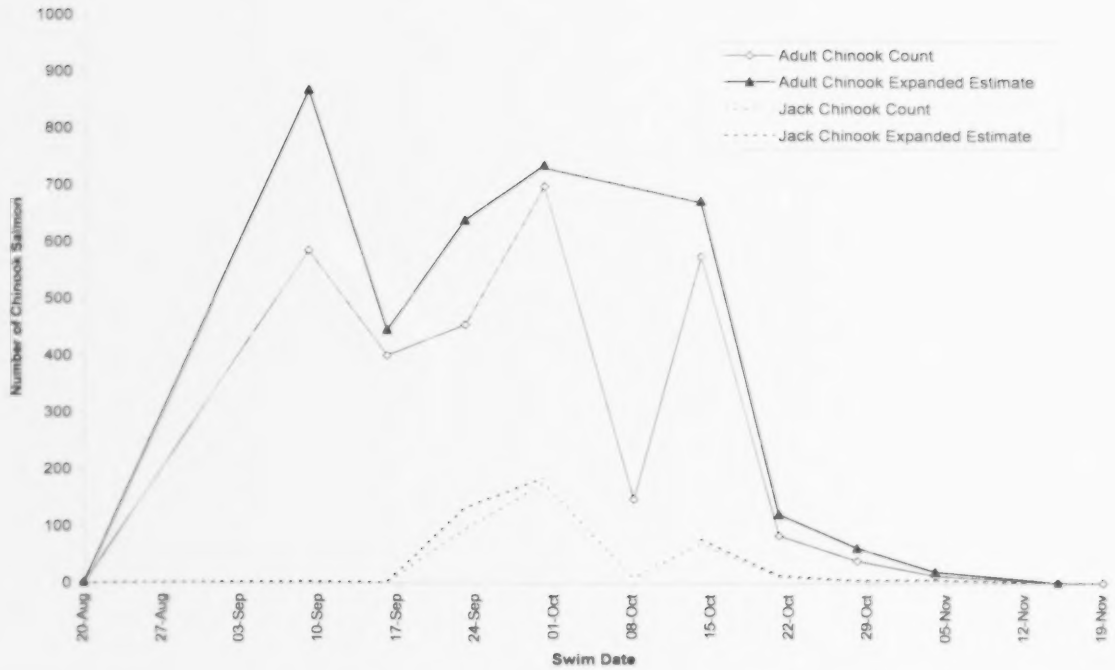


Figure 5. Swim survey counts and expanded system estimates, lower Nanaimo River, 2004.

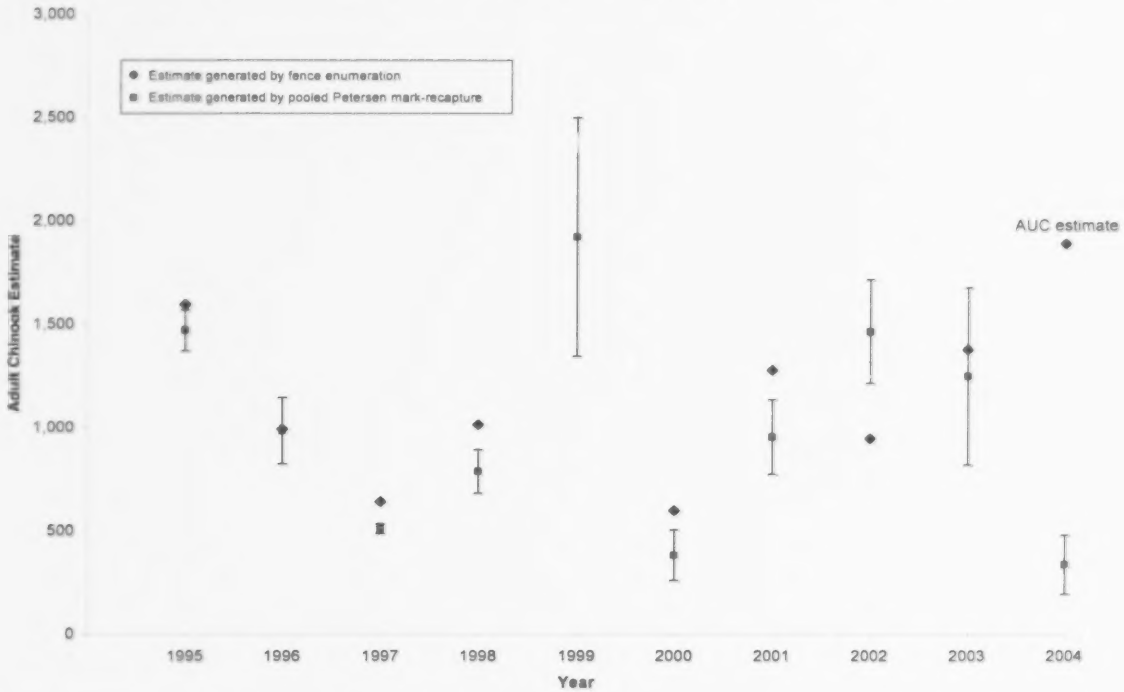


Figure 6. Annual comparisons of fall run adult chinook population estimates generated by fence information and mark-recapture pooled Petersen calculations (with 95% confidence intervals), lower Nanaimo River, 1995 – 2004.

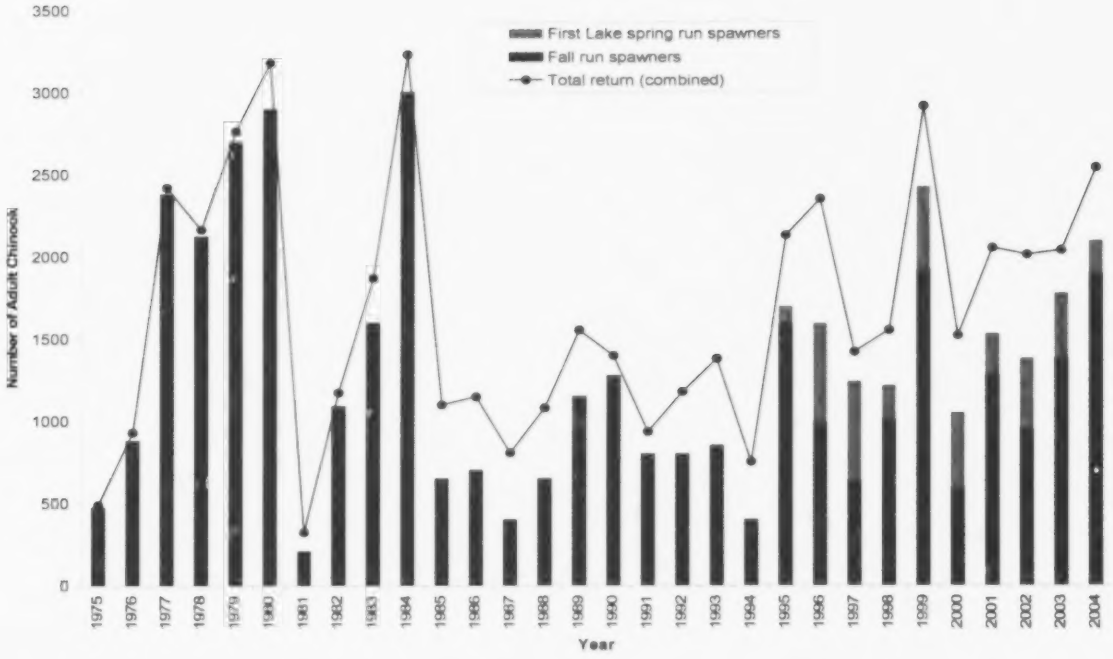


Figure 7. Annual adult chinook escapement estimates, Nanaimo River, 1975 – 2004.

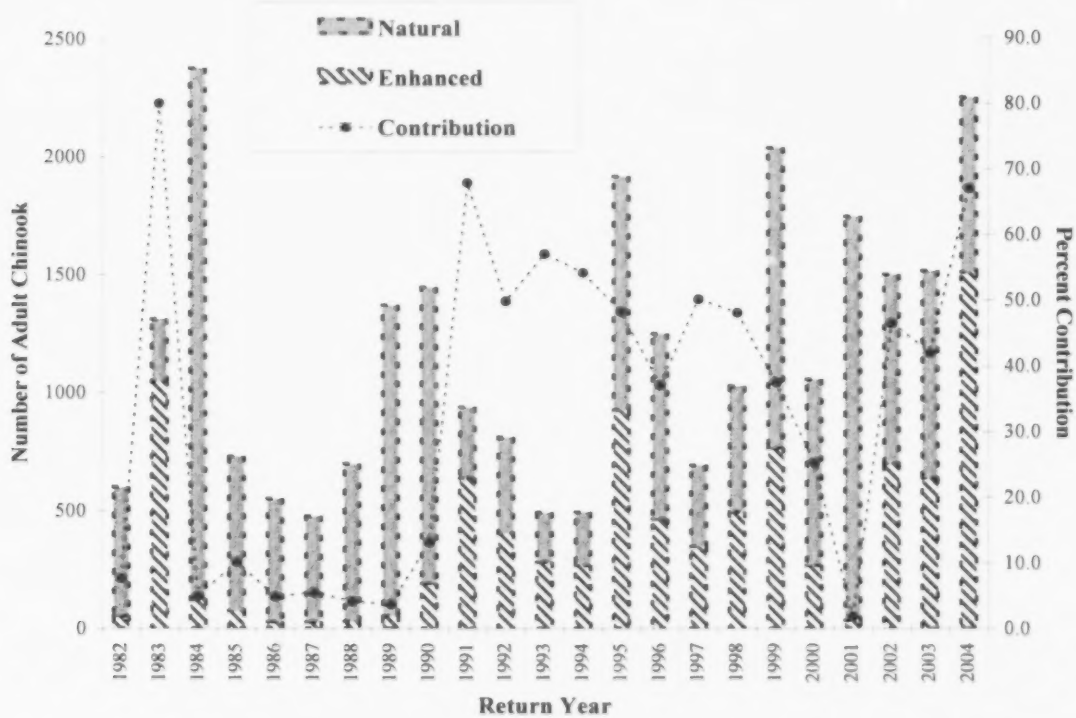


Figure 8. Annual natural and enhanced contributions to fall run adult chinook escapement, Nanaimo River 1982 – 2004.